Status of terrestrial mammals at the Kafue-Zambezi Interface: Implications for transboundary connectivity.

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The Kavango-Zambezi Transfrontier Conservation Area Programme promotes landscape-level connectivity between clusters of wildlife managed areas in five neighbouring countries. However, declining regional biodiversity can undermine efforts to maintain, expand and link wildlife populations. Narratives promoting species connectivity should thus be founded on studies of system and state changes in key resources. By integrating and augmenting multiple data sources throughout eight wildlife managed areas covering 1.7m ha, we report changes from 1978-2015 to the occurrence and distribution of 31 mammal species throughout a landscape linking the Greater Kafue System to adjacent wildlife managed area in Namibia and Botswana. Results indicate species diversity was largely unchanged in Kafue National Park, Mulobezi and Sichifulo Game Management Areas. However 100% of large carnivore and 64% of prey diversity have been lost in the Simalaha areas. No evidence of migrational behaviour or species recolonisation from adjacent wildlife areas was established. While temporal sampling scales impacts the definition of species occupancy and distribution, and data cannot elaborate on population size or trends, findings indicate an emerging connectivity bottleneck within Simalaha. At current disturbance levels, evidence suggests the Greater Kafue System, Zambia's majority component in the Kavango-Zambezi Transfrontier Conservation Area, is becoming increasingly isolated at the large mammal scale contrary to prevailing narratives. Further investigations of the site-specific, interacting drivers impacting wildlife distribution and occurrence are required to provide management with appropriate conservation interventions aimed at wildlife recovery in key areas identified to promote transboundary connectivity in the Kavango-Zambezi Transfrontier Conservation Area.

Keywords: Kavango-Zambezi Transfrontier Area, Kafue, connectivity, mammal loss.

Introduction

Wildlife managed areas are frequently clustered along international borders, with arbitrarily drawn political boundaries dividing ecosystems in which these areas occupy (Zbicz, 1999a; Hanks, 2000). Where fences and physical barriers combined with expanding human settlement and intensifying agropastoralist activities, over-exploitation and extreme wildlife population decline can occur (Ogutu et al., 2016). Additionally invasion, disease, pollution and climate change (Maxwell et al., 2016; Pachauri et al., 2014) interact with intrinsic species traits (Cardillo et al., 2008) to inhibit or sever wildlife movement patterns, isolating core wildlife managed areas (Margules & Pressey, 2000; Newmark, 2008). In concert these drivers are exposing wildlife populations to escalating edge-effects and ecological traps, threatening species persistence within and outside protected areas (Woodroffe & Ginsberg, 1998; Battin, 2004). Conversely, intact species assemblages have wide-ranging implications for sustainable and resilient social-ecological systems (Cummings, 2011). Heterogeneity and functional diversity drives system productivity and its capacity to absorb, resist and respond to shocks, perturbations and other stressors that negatively impact system structure and function (Fischer et al., 2006). Cumulatively threats to species persistence undermine habitat integrity, ecosystem services, food security, the development of sustainable wildlife-based land uses and human wellbeing (Lindsay et al., 2013; WHO/MEE, 2005).

Acknowledging the limitations imposed by these constraints, stakeholders in Southern Africa are increasingly embracing Transfrontier Conservation Areas (TFCAs) as a new conservation paradigm (Hanks, 2000), considered an evolution of previous Community Based Natural Resource management approaches that yielded mixed results (Andersson, 2016). Enticing narratives include the integration of biodiversity conservation with the promotion of sustainable socioeconomic development and a culture of peace and cooperation at the ecosystem level, linked to the removal of fences and other barriers inhibiting the free movement of wildlife across vast interconnected landscapes (Linde et al., 2002, Hanks, 2003). The Kavango-Zambezi Transfrontier Conservation Area is working to capitalise on the regions' unique diversity and distribution of wildlife assets by advocating shared natural resource management and development goals across an immense network of protected areas spanning over 500,000km^2 at the interface of Angola, Botswana, Namibia, Zambia and Zimbabwe (KAZA, 2011b; Hanks & Myburgh, 2015). Stated objectives to integrate conservation and development, promote peace and cooperation, and facilitate connectivity of wildlife populations between clusters of wildlife managed areas have become popular and compelling programme narratives driving north-south finance initiatives, non-government organisation engagement, and energising State buy-in (KAZA, 2011a; PPF, 2008; WWF, 2011).

Notwithstanding evolving conservation and development narratives, the Kavango-Zambezi TFCA landscape faces many existing and emerging challenges constraining programme success. Mounting anthropogenic pressures combined with poor land use planning, institutional conflicts and stakeholder disenfranchisement (Andersson, 2016), are driving encroachment into wildlife areas, habitat loss and fragmentation (Watson et al., 2015; Newmark, 2008; Simukonda, 2008), and unsustainable harvesting of wildlife, threatening many of the Kavango-Zambezi TFCA's iconic natural assets (Lindsay et al., 2013). With the regions human population expected to double by 2050 (UN, 2015) and likely impacts of climate change exacerbating socioeconomic development challenges (Pachauri, et al., 2014; Bellard et al., 2012), even moderately optimist scenarios imply regional biodiversity loss will accelerate significantly this century (Briggs et al., 2008).

Collectively these challenges raise important questions surrounding the scope, scale and ambition of narratives promoting landscape-level linkages, the interventions required to maintain or expand connectivity, and what purposes these proposed linkages may serve in the long term (Cumming, 2008). A clear imperative thus exists to promote evidence-based socioeconomic and environmental policies and interventions built around the application of conservation science (Sutherland et al., 2004), including research and monitoring of changes to site and system states, and their response to factors driving connectivity at the scale of interest. But the process of informed decision making is data hungry. Local, regional and transboundary data sources are disparate and inconsistent, undermining attempts to understand complex social ecological systems such as the Kavango-Zambezi TFCA. Data deficiencies ultimately constrain effective decision making and appropriate interventions to promote biodiversity conservation and development.

In this paper we interrogate and synthesise existing data sources, and supplement with additional research to document the historical and contemporary status of the African Elephant (Loxodonta africana), five large carnivores, one mesopredator and twenty four prey species throughout eight wildlife managed areas between the Greater Kafue System and the Zambezi River. This landscape is promoted as a key linkage to the central cluster of wildlife managed areas in Namibia and Botswana, at the heart of the Kavango-Zambezi TFCA (KAZA, 2014).

Through integration, harmonisation and triangulation of data we were able to determine changes to species occurrence and distribution by wildlife managed area and designation.

Methods:

Study Area

While the Kavango-Zambezi TFCA's boundaries are imprecise (Andersson, 2016), Cummings (2008) characterises the TFCA as comprising a matrix of over 70 wildlife managed areas from strict national parks under state control to multiple use areas under community management. These wildlife managed areas fall into three major clusters and five periphery sub-clusters, with Kafue National Park and surrounding wild-life managed areas constituting the major northern cluster (Fig. 1).

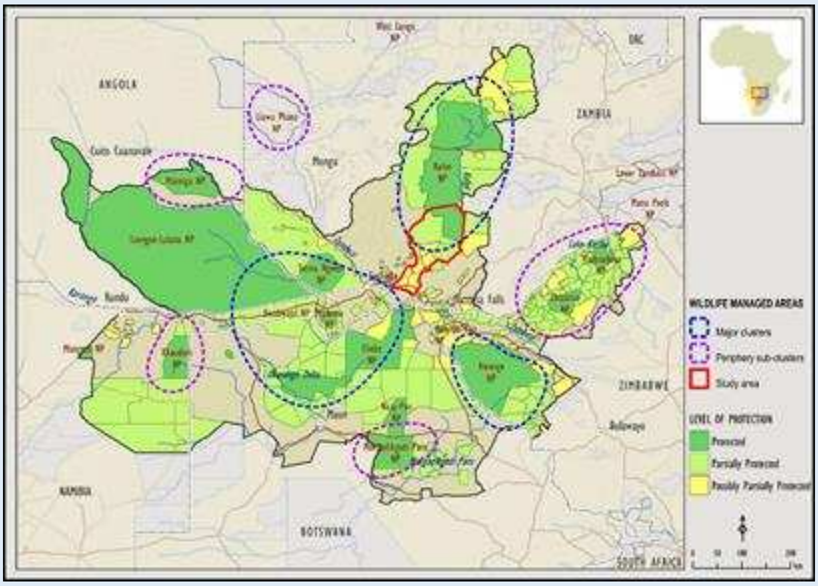

Figure 1: The Kavango-Zambezi TFCA landscape, indicating clusters of wildlife managed areas (adapted from PPF, 2011).

At 22,480km^2 Kafue National Park is Zambia's oldest and largest protected area, the largest National Park in the Kavango-Zambezi TFCA and 2nd largest National Park in Africa (UNEP/WCMC, 2016). In concert with nine surrounding IUCN category VI Game Management Areas and multiple Forest Reserves, the effective unfenced wildlife managed area, termed variously as the Greater Kafue Landscape or System, covers 68,000 km^2 – a vast undeveloped area approximately half the size of England, and representing 9% of Zambia's land mass and over 13% of the Kavango-Zambezi TFCA estate.

Most of the Greater Kafue System lies between 900-1100m above sea level. Rainfall averages 650mm in the south and 1,050mm in the north, falling predominantly from November to April. Vegetation is characterised by the Zambezian Miombo woodland Ecoregion, typical of large areas throughout southern and eastern Africa, dominated by Brachystegia sp., Combretum sp., Mopane sp., Terminalia sp. and Baikaea sp. Woodlands are interspersed by open floodplain grasslands and dambos (ZAWA, 2010). Species records include 158 mammals, 481 birds, 69 reptiles, 35 amphibians and 58 fish, with the greatest antelope diversity in Africa (21 species), an intact carnivore guild and a full complement of Zambia's large mammals with exception of Giraffe (Giraffa giraffa), Black Rhinoceros (Diceros bicornis) and Tsessebe (Damaliscus lunatus) (Moss, 2012).

The Greater Kafue System has been included as Zambia's majority component within Kavango-Zambezi TFCA (KAZA, 2014), with connectivity to the broader Kavango-Zambezi landscape contingent on the maintenance of a landscape level linkage routing south-southwest through a mosaic of nominally, potentially and possibly protected wildlife managed areas including Mulobezi and Sichifulo Game Management Areas, Nachitwe, Martin and Machili Forest Reserves, the Nyawa communal areas, and the recently proclaimed Simalaha Communal Conservancy (Fig. 2). In concert these wildlife managed areas extend the Greater Kafue System to around 7.3m ha.

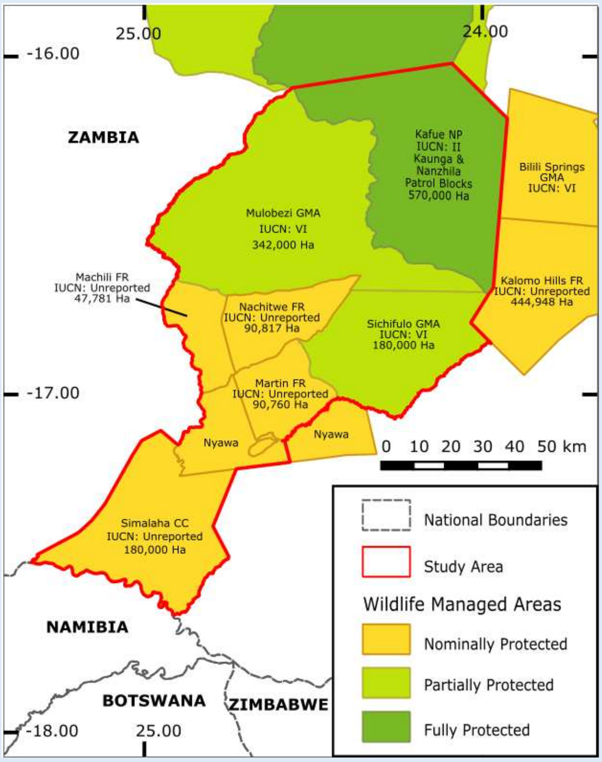

Figure 2: Wildlife managed areas within study area.

A secondary (south-westerly) linkage passing through Mulobezi to Sioma NP (bordering Namibia and Angola) has been proposed, though our focus remains the linkage broadly following the Machili stream catchment basin from the Kafue NP border (S16.138^{0}, E25.365^{0}) to the northern bank of the Zambezi River

(S17.555^0, E24.977^0), adjacent to Kasika and Salambala Communal Conservancies of East Zambezi Region in Namibia, and through to Chobe NP in Botswana.

The proposed landscape linkage varies in length from 140-170km. The human population is around 110,000 and growing at 2.5% pa, with a population density ≈4.0/km^2 (CSO, 2010). Communities are centred on a few larger settlements of 5,000-10,000 residents, and otherwise in clusters of scattered villages typically concentrated along water courses, seasonal waterholes, and few pumped ground water supplies. Subsistence agro-pastoralists dominate this landscape, with residents largely dependent on exploiting a wide range of the area’s natural resources in support of basic livelihood needs (Musgrave, 2016). Formal employment opportunities beyond few distant urban settlements are negligible. Customary law within the Lozi, Nkoya, and Tonga ethnolinguistic groups represent the de facto regional governance system (Brelsford, 1965; Musgrave, 2016).

Biodiversity conservation budgets have varied dramatically throughout this landscape, both spatially and temporally. While precise figures are unavailable, sources indicate that Kafue National Park (although operating with 10-15% of recommended protected area budgets) has received the greatest level of long term biodiversity conservation support throughout the study area. This is followed by Mulobezi then Sichifulo Game Management Areas which receive minor budget allocations from the State Wildlife Authority, augmented by finance and in-kind operational support from resident safari hunting operators and conservation NGOs. Nachitwe, Martin and Machili Forest Reserves have intermittently received minor budgets from the State Wildlife Authority and Forestry Department (ZAWA, 2010; Chifunte, pers comms). The recently proclaimed Simalaha Communal Conservancy only started receiving any formal wildlife resource protection as recently as 2013 following no formal biodiversity conservation budgets since pre-1978 (Inyambo-Yeta, pers comms). We were unable to ascertain if the Nyawa Communal areas receives any formal wildlife management budget. In additional a 24,000ha fenced Wildlife Recovery Sanctuary at the south of Simalaha, with an extensive open border against the Zambezi River, has received >600 head of game from eight species since 2013, representing a significant investment promoted as a justification for restocking the broader Simalaha Communal Conservancy (PPF, 2015).

Data Sources

The earliest records of terrestrial mammal occurrence and distribution in the vicinity of the proposed Kafue-Zambezi linkage are limited to disparate notes and reports in the grey literature from early explorers, hunters, traders and missionaries dating back to the late 19th century (e.g. Holub, 1975; Sampson, 1972), with approximate location data variously reported in relation to key landscape features. The first published checklists for Zambia (Pitman, 1934; Lancaster, 1953; Ansell, 1957/59/60) indicate no changes to the large mammal assemblage in and around Kafue NP prior to the notable Black Rhinoceros extirpation in the mid-1980's, though unresolved questions surround anecdotal records of a relic Giraffe population (Moss, pers comms). Data for these checklists were ostensibly collected through ad hoc and opportunistic sightings from Government staff and 'expert' observers reporting from their travels throughout the country, augmented by trading records and hunting ledgers kept by District Commissioners.

The first systematic collation of species occurrence and distribution data was published by Ansell (1978), superseding previous literature. Amalgamated checklist data were mapped within ¼ degree grid squares, based on 1:50,000 Ordinance Survey map sheets. While data reflects minimum regional species range given the absence of reports from many inaccessible and largely unmapped periphery areas, much of this study area can be considered well mapped due to the established network of access routes developed alongside the nascent Teak logging and safari hunting industries (Musgrave, 2016).

While Ansell (1978) reports on 38 terrestrial mammals >10kg from 11 taxonomic families we restricted the contemporary list to 31 readily detected species from nine taxonomic families, omitting seven species considered either at the edge of known range and/or habitat specialists requiring species-specific survey techniques beyond the scope of this study.

Boundaries of contemporary land use classifications (UNEP-WCMC, 2016) were projected over Ansell's (1978) maps using QGIS (QGIS, 2017) (Fig 3) to allow for extraction of historical species distribution data at comparable spatial scales: Kafue National Park (Kaunga and Nanzhila management blocks at 570,000ha), Mulobezi Game Management Area (hereafter Mulobezi, at 342,000ha), Sichifulo Game Management Area including Nachitwe, Martin and Machili Forest Reserves (hereafter Sichifulo, at 409,000ha), and finally the Nyawa/Simalaha areas (around 280,000ha).

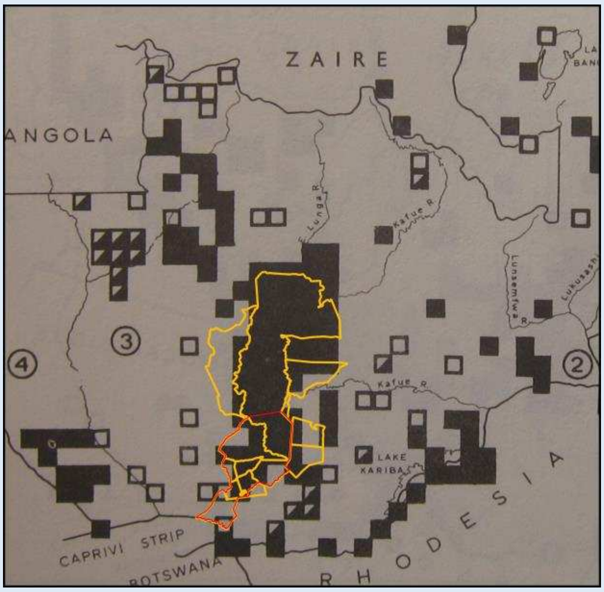

Figure 3: Data from Ansell (1978) showing species known range (solid squares), possible range (hatched squares) and former range (unfilled squares), mapped here for Blue Wildebeest (Connochaetes taurinus). Boundary of contemporary wildlife managed areas in yellow, study area in red.

In compiling contemporary data sets (Fig 4) we constrained data gathering to three broadly comparable ground-based survey approaches. We omitted aerial survey data (e.g. DNPW, 2016) given limitations to detection rates for many species of primary interest in forested areas (Jachmann, 2002). Firstly the resident safari hunting operator, operational throughout Mulobezi and Sichifulo during the preceding decade, was asked to provide sightings reports for 31 terrestrial mammals of interest through a questionnaire survey following the 2014 hunting season. Cumulatively, multiple groups of guides, hunters and skilled trackers traverse both Mulobezi and Sichifulo on and off road, covering >10,000km/dry season (Kraljic, pers comms). This was considered sufficient survey effort and expertise to detect target species. Secondly we collected patrol data from the local State and Community Wildlife Police Officers responsible for wildlife protection in southern Kafue NP, Mulobezi and Sichifulo. We amalgamated data for the Kafue NP patrol blocks adjacent to Mulobezi and Sichifulo to provide a single area covering the border north of both Mulobezi and Sichifulo Game Management Areas. These data provided 1,920 georeferenced wildlife sightings during 2014/5 from 46,170 man-days of foot patrols (ZAWA, unpublished data). Finally, in 2015, we undertook a systematic randomised spoor and sightings survey of large carnivores and their principle prey throughout 10 x 400km^2 survey blocks in Mulobezi, Sichifulo and the Nyawa/Simalaha areas. Detection probability and survey effort were optimised for large carnivores following Funston et al. (2010) and Thorn et al. (2010). In addition, a site-specific calibration process was undertaken from July to September 2014, conducted at varying spatiotemporal scales, to establish survey effort required to detect large carnivores and sample the landscape in a single season (MacKenzie & Royle, 2005, MacKenzie, pers comms). In total 102 x 4km transects were walked three times by the principle investigator and two experienced local trackers from the safari hunting industry, cumulatively providing 1,224km of spoor transects over six months fieldwork during the dry season from May and Oct 2015.

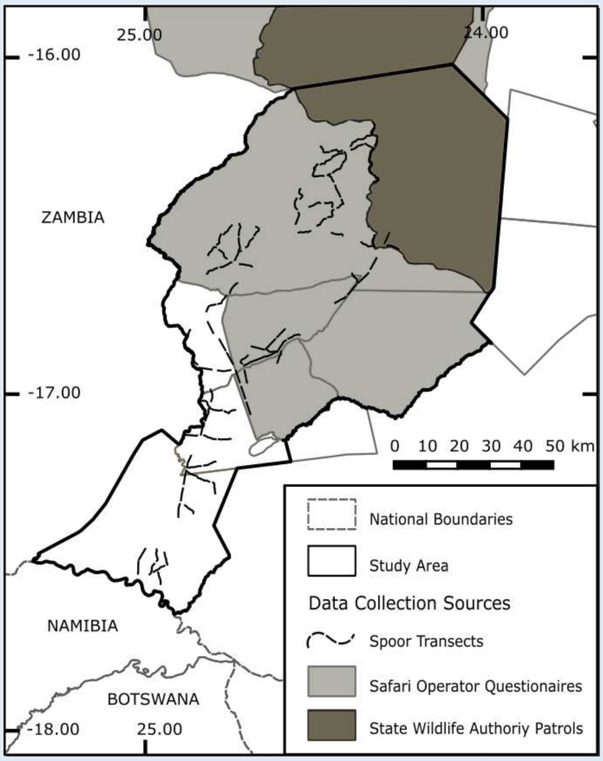

Figure 4: Data sources for contemporary analyses.

Data Analysis

A confirmed sighting from any of the three selected expert contemporary sources was considered sufficient to detect species presence at the scale of interest. Given the atypical nature of ongoing ungulate reintroductions and management in the fenced Simalaha Wildlife Sanctuary, we restrict reporting to the detection of the carnivore guild for this subset of the Simalaha Communal Conservancy.

Data for each of the four composite wildlife management area blocks and three data sources were compiled against historical data to determine if any changes in species occurrence and distribution had been detected throughout the intervening years. Outputs reflected species persistence, loss or colonisation at the composite wildlife management area scale.

Given survey methods were optimised for resident large carnivores and their principle prey species, elevated non-detection risks existed where species exhibited significant seasonal movement patterns (migration), non-resident movement patterns (emigration and immigration), or where surveys did not cover the restricted ranges of habitat specialists. Table 1 and subsequent analyses acknowledges these constraints.

Finally an amalgamated distribution map was generated for the five extant large carnivores, indicating historical range within the survey area, and current known range within studied wildlife managed areas.

Results: Changes to Species Occurrence and Distribution

Table 1 indicates few non-detections recorded against any data sources since 1978 throughout southern Kafue National Park, Mulobezi or Sichifulo areas. Notably Hippopotamus (Hippopotamus amphibius) appear no longer resident in any of the waterways along the Machili stream and catchment area. Klipspringer (Oreotragus oreotragus) appear absent from Mulobezi, though core habitat for this species went unsurveyed. Steenbok (Raphicerus campestris) are considered at the extent of their northeast range approaching Kafue NP, with a single sighting recorded in Mulobezi.

Species binomial	Common Name	IUCN	Ansell 1978				Kraljik 2013/4		ZAWA 2014/5			Lines 2014/5			Distribution Change 1978-2014/5			
		Status	KNP/S	Mulobezi	Sichifulo	Simalaha	Mulobezi	Sichifulo	KNP/S	Mulobezi	Sichifulo	Mulobezi	Sichifulo	Simalaha	KNP/S	Mulobezi	Sichifulo	Simalaha
Acinonyx jubatus	Cheetah	VU	✓	✓	✓	✓	✓	✓	✓	X	X	✓	✓	X	No	No	No	Yes
Panthera leo	Lion	VU	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes[1]
Panthera pardus	Leopard	VU	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	No	No	No	Yes[1]
Crocuta crocuta	Spotted Hyena	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes[1]
Canis adustus	Side-striped Jackal	LC	✓	✓	✓	✓	✓	✓	✓	X	X	✓	✓	✓	No	No	No	No
Lycaon pictus	African Wild Dog	EN	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Loxodonta africana	African Bush Elephant	VU	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes[1]
Equus quagga	Burchell's Zebra	NT	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes[2]
Phacochoerus africanus	Warthog	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Potamochoerus larvatus	Bushpig	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Hippopotamus amphibius	Hippopotamus	VU	✓	✓	✓	✓	X	X	✓	X	X	X	X	X	No	Yes[1]	Yes[1]	Yes[1]
Alcelaphus lichtensteiniix	Hartebeest	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Connochaetes taurinus	Blue Wildebeest	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes[2]
Oreotragus oreotragus	Klipspringer	LC	✓	X	✓	X	✓	✓	✓	X	X	X	X	X	No	No	No	No
Ourebia ourebi	Oribi	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	No	No	No	No
Raphicerus campestris	Steenbok	LC	✓	✓	✓	✓	X	X	X	X	X	✓	X	X	UK[3]	No	Yes	Yes
Raphicerus sharpei	Sharpe's Grysbok	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	No	No	No	No
Syncerus caffer	African Buffalo	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Tragelaphus oryx	Common Eland	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	X	No	No	No	Yes
Tragelaphus scriptus	Bushbuck	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Tragelaphus spekii	Sitatunga	LC	✓	X	X	X	X	X	X	X	X	X	X	X	Yes	No	No	No
Tragelaphus strepsiceros	Greater Kudu	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	No	No	No	No
Sylvicapra grimmia	Common Duiker	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	No	No	No	No
Hippotragus equinus	Roan Antelope	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Hippotragus niger	Sable Antelope	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes
Aepyceros melampus	Impala	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes[2]
Kobus ellipsiprymnus defassa	Defassa Waterbuck	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	X	No	No	No	Yes[2]
Kobus leche	Lechwe	LC	X	X	X	✓	X	X	X	X	X	X	X	X	No	No	No	Yes[2]
Kobus vardonii	Puku	NT	✓	X	X	X	X	X	✓	X	X	X	X	X	No	No	No	No[2]
Redunca arundinum	Southern Reedbuck	LC	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	No	No	No	No
Hystrix africaeaustralis	Cape porcupine	LC	✓	✓	✓	✓	✓	✓	X	X	X	✓	✓	✓	No	No	No	No

[1] Non-resident individuals periodically reported by local community moving through the area
[3] Extent on known range
[2] Reintroduced in fenced 24,000ha breeding camp 2013-5

Table 1: Summary results of species detection by source and area, with distribution change, 1978-2014/5.

The absence of confirmed Caracal (Caracal caracal) and Serval (Leptailurus serval) sightings by Wildlife Police Office patrols in southern Kafue NP appear an anomaly given detection from adjacent Game Management Areas. Though it is likely this anomaly represents non-detection error versus absence, we discarded these species from the final check list.

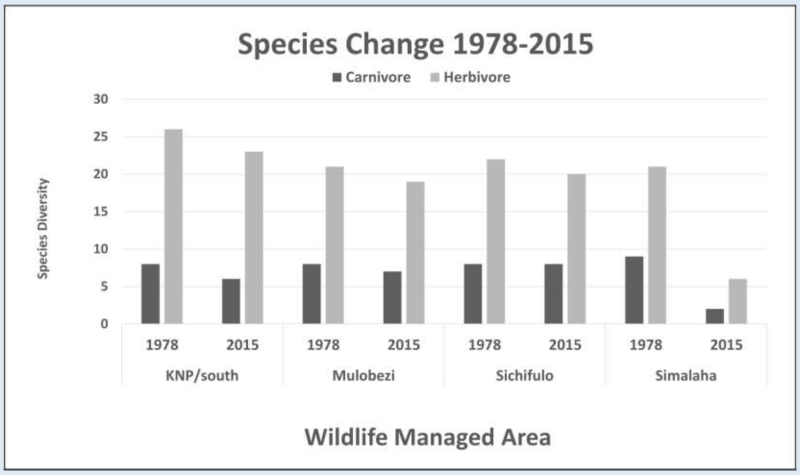

Figure 5: Changes to carnivore and herbivore composition by area, 1978-2014/15.

Significant losses have occurred in the newly registered Simalaha Communal Conservancy, whereby 21/31 terrestrial mammals went undetected (Fig 5). Side-stripped Jackal (Canis adustus) remained the only widespread carnivore detected in Simalaha. Both Spotted Hyaena (Crocuta crocuta) and Leopard (Panthera pardus) were the only large carnivores detected within 60km of the Zambezi River in the Nyawa Communal area (Fig 6). The remaining large carnivore guild appears extirpated from the Simalaha/Nyawa area along with all ungulates >20kg, excluding the Southern Reedbuck (Redunca arundinum) and Greater Kudu (Tragelaphus strepsiceros). Kudu were also the only herding ungulate to be detected in Simalaha, through no aggregations over three animals were detected. Notably both Warthog (Phacochoerus africanus) and Bushpig (Potamochoerus larvatus), habitat and feeding generalists with high reproductive rates, went undetected in Simalaha. While >600 head of game comprising seven species have been introduced into the 24,000ha Simalaha Wildlife Recovery Sanctuary since 2013, only Side-Stripped Jackal were detected inside the (non-predator proof) area. There was no evidence of any species range extension or recolonisation throughout any of the sampled areas.

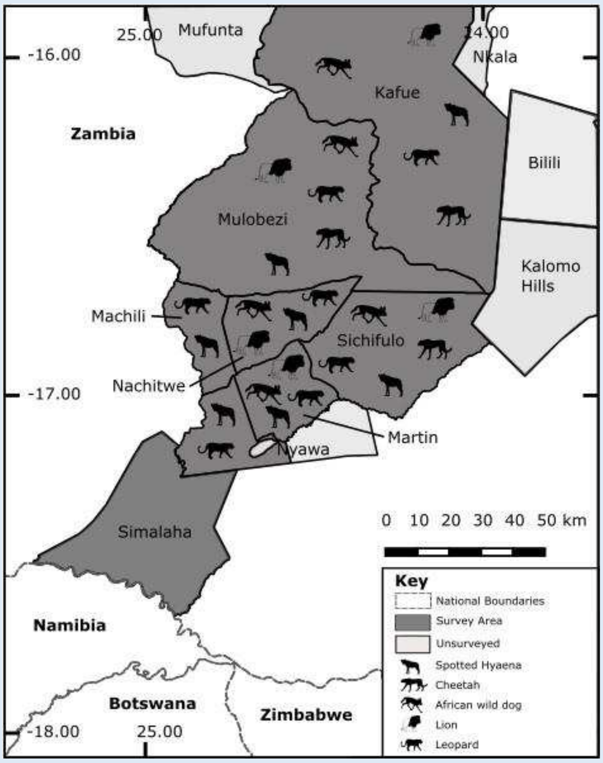

Figure 6: Distribution of large carnivores at Kafue-Zambezi Interface, 2014/5.

Although no long term, comparable, or landscape-level survey programme is in place to systematically monitor changes in species occurrence, distribution or abundance, much existing expertise and anecdotal evidence implies large scale population declines throughout the Greater Kafue System and beyond since 1978 (Chifunte, Daka, Hanks, Moomba, Moss & Yeta, pers comms). Contemporary data indicates Kafue NP, the regions' prime wildlife area, is maintaining the majority of terrestrial mammals significantly below carrying capacity (Simukonda, 2008). Nonetheless, with few historical survey data available for direct comparison, we restricted our analyses to species diversity at the scale of interest, versus any interpretation of spatiotemporal changes to community structure and abundance, which is beyond the scope of this paper.

Discussion

Formal historical records explaining species loss in Simalaha and Nyawa areas are unavailable, though local Traditional Authorities (Chiefs Inyambo-Yeta, Moomba, pers comms) emphasised the impact of the Angolan Bush War (1966-1989) as a key driver, describing the activities of foreign combatant encampments in Simalaha being used as a base to exploit the areas' wildlife for rations and profit. Following cessation of hostilities much small arms proliferation occurred, and in conjunction with expanding human population and limited funding for law enforcement and natural resource management, ongoing unsustainable harvesting of wildlife continued. Given these circumstances the authors hypothesise that wildlife managed areas closer to Kafue National Park were spared much of these pressure, having also received elevated political and revenue support for wildlife management in the long term (Daka, pers comms).

Existing surveys at the Kafue-Zambezi interface have employed a range of ad hoc methodological approaches that failed to detect the majority of resident species throughout this landscape. The absence of a reliable baseline undermines efforts at evaluating the effectiveness of large scale conservation interventions required to deliver key programme objectives within and between clusters of wildlife management areas.

Acknowledging non-detection error, we confirm that the terrestrial mammal (>10kg) diversity in southern Kafue NP remains unchanged since 1978. Mulobezi and Sichifulo retain largely intact mammalian diversity, with the notable exception of resident Hippopotamus. No new data could be provided for the existence of free-ranging Giraffe in any of these wildlife managed areas.

While a single season survey design increases non-detection error associated with species dispersal or seasonal wildlife movement patterns, widespread losses, including three of six carnivore species and 16 of 25 prey species, were detected in the Simalaha Communal Conservancy / Nyawa areas, collectively key linking wildlife managed areas at the interface of the Greater Kafue System and adjacent wildlife managed areas in Namibia and Botswana.

These data emphasise the challenges surrounding scope and scale of conservation interventions required to limit factors driving species loss from seven of nine taxonomic families, representing a wide range of species traits. Significantly, if drivers of species loss continue to limit population recovery in Simalaha/Nyawa areas then source-sink dynamics and edge effects can negatively impact population viability of vulnerable species in periphery wildlife managed areas at local and transboundary scales.

Wide-ranging species are particularly susceptible to source-sink dynamics and edge effects, so the absence of large carnivores from the Simalaha and the Simalaha Wildlife Recovery Sanctuary indicates the need for additional research to understand the status and drivers of wildlife occurrence and distribution south of the Zambezi River throughout the wildlife managed areas of eastern Zambezi Region in Namibia, and the effects that ecological traps/attractive sinks might pose at transboundary scales on wildlife management interventions in Simalaha and other neighbouring wildlife managed areas of Zambia.

Broader scale implications of species loss and ecological traps within the Kavango-Zambezi TFCA relate to dominant narratives surrounding wildlife managed area connectivity. The extent to which existing and emerging drivers of species loss are severing biological linkages between the Greater Kafue System and adjacent wildlife managed areas in the Kavango-Zambezi TFCA remain unquantified and subject to speculation. However data suggests a connectivity bottleneck at the large mammal level in the Simalaha Communal Conservancy, with only 10 of 31 species known from historical records detected throughout this area in 2014/5.

While the long distance dispersal capabilities of large carnivores implies scope for gene flow between the Greater Kafue System and adjacent wildlife managed areas in the Kavango-Zambezi TFCA, the extent to which connectivity bottlenecks impact processes of immigration and emigration in highly mobile species is an important area of priority research for regional connectivity conservation management.

Conclusions

The study focused on ascertaining changes to the occurrence and distribution of 38 terrestrial mammals >10kg known from four composite wildlife managed areas between the Greater Kafue System and central cluster of wildlife managed areas in the Kavango-Zambezi TFCA, and the methodological approach was successful for 31 species at the scale of interest.

While these data cannot elaborate on population numbers and trends, it is apparent that ongoing attempts to maintain population viability of vulnerable species, wildlife connectivity between clusters of wildlife managed areas, and the promotion of wildlife-based land uses, will depend on diagnosing and treating the interacting ecological, socio-economic and political drivers of species loss within and between clusters of wildlife managed areas utilising comparative studies at appropriate temporal and spatial scales.

The limits to which sufficient political and economic capital can be leveraged to bridge these knowledge gaps, act accordingly on the findings, and be subject to monitoring, evaluation and feedback, will likely determine future connectivity for Zambia’s majority component within the Kavango-Zambezi TFCA.

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Author contributions

R. Lines designed and undertook fieldwork and write up, with input from J. Tzanopoulos and D. MacMillan on structure and analysis. No conflict of interested are reported.

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